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ABSTRACT

More than 20,000 kindergarten through 12th grade teachers and more than 6,000 college and university faculty are directly involved in National Science Foundation (NSF) education projects. Building on more than 4 decades of knowledge and experience, NSF today is able to provide vigorous leadership in the nation's efforts to strengthen science, mathematics, and engineering education. This profusely illustrated booklet describes the diverse and vigorous education and human resource programs the NSF has developed and supported over the last 10 years--activities that reach out to all, recognizing the needs of a changing U.S. population and a changing workplace. Sections in this booklet include: (1) Teachers and Faculty; (2) Classroom and Laboratory Tools; (3) Applying Technology to Education; (4) Learning How People Learn; (5) NSF Education Goals; (6) Leadership and Systemic Reform; (7) Beyond the Classroom; (8) Increasing Diversity; (9) Encouraging Excellence; (10) Monitoring Trends; (11) Coordinating a Federal Strategy; and (12) For Further Information. (PR)

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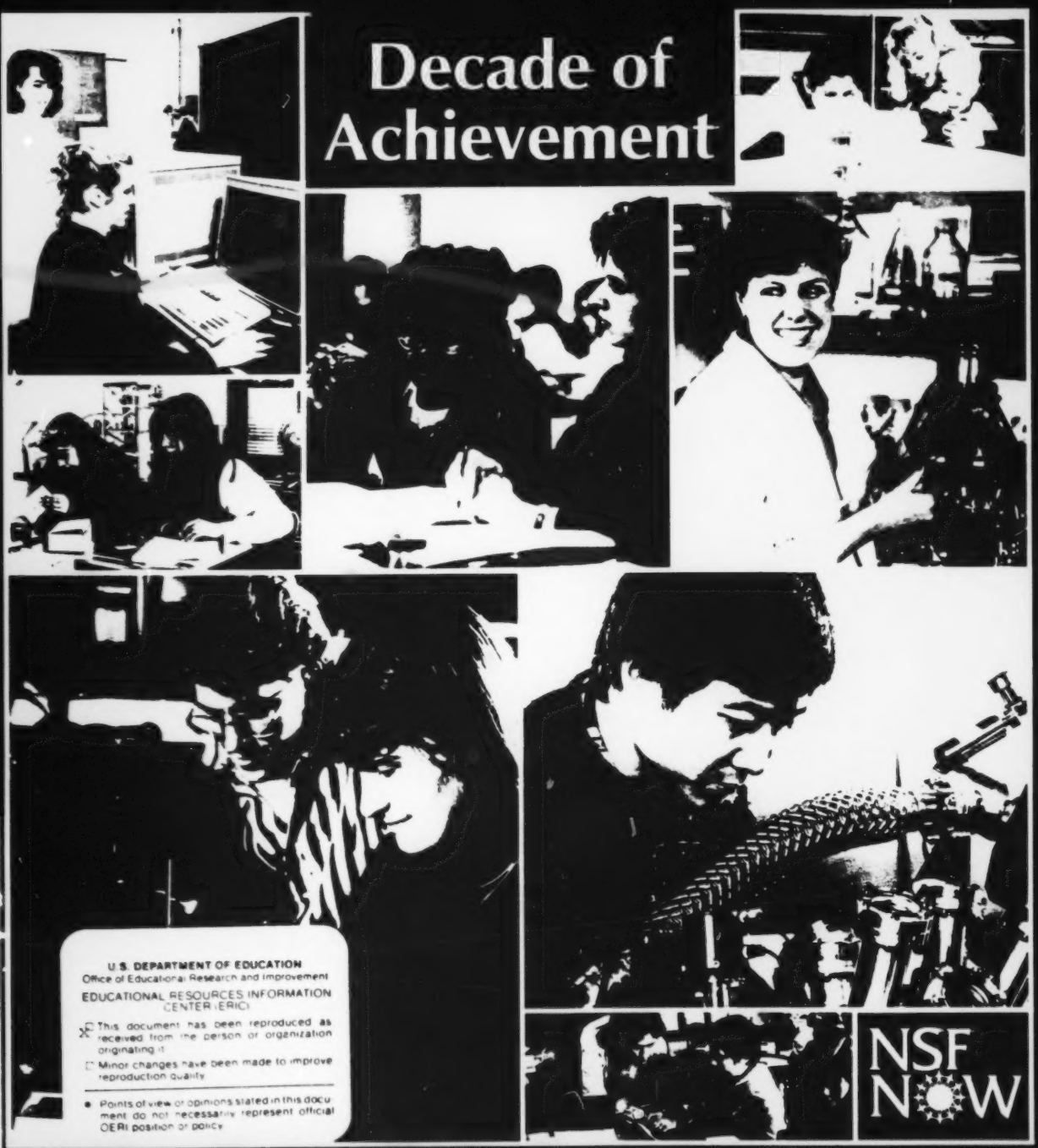
Decade of Achievement



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NSF NOW

Educational Leadership in Mathematics, Science and Engineering

National Science Foundation
Directorate for Education and Human Resources

SE 053 516

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National Science Foundation Act of 1950

The National Science Foundation was established by Congress in 1950 "to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels in the mathematical, physical, medical, biological, social, and other sciences and to initiate and support research fundamental to the engineering process and programs to strengthen engineering research potential and engineering education programs at all levels. . . ."

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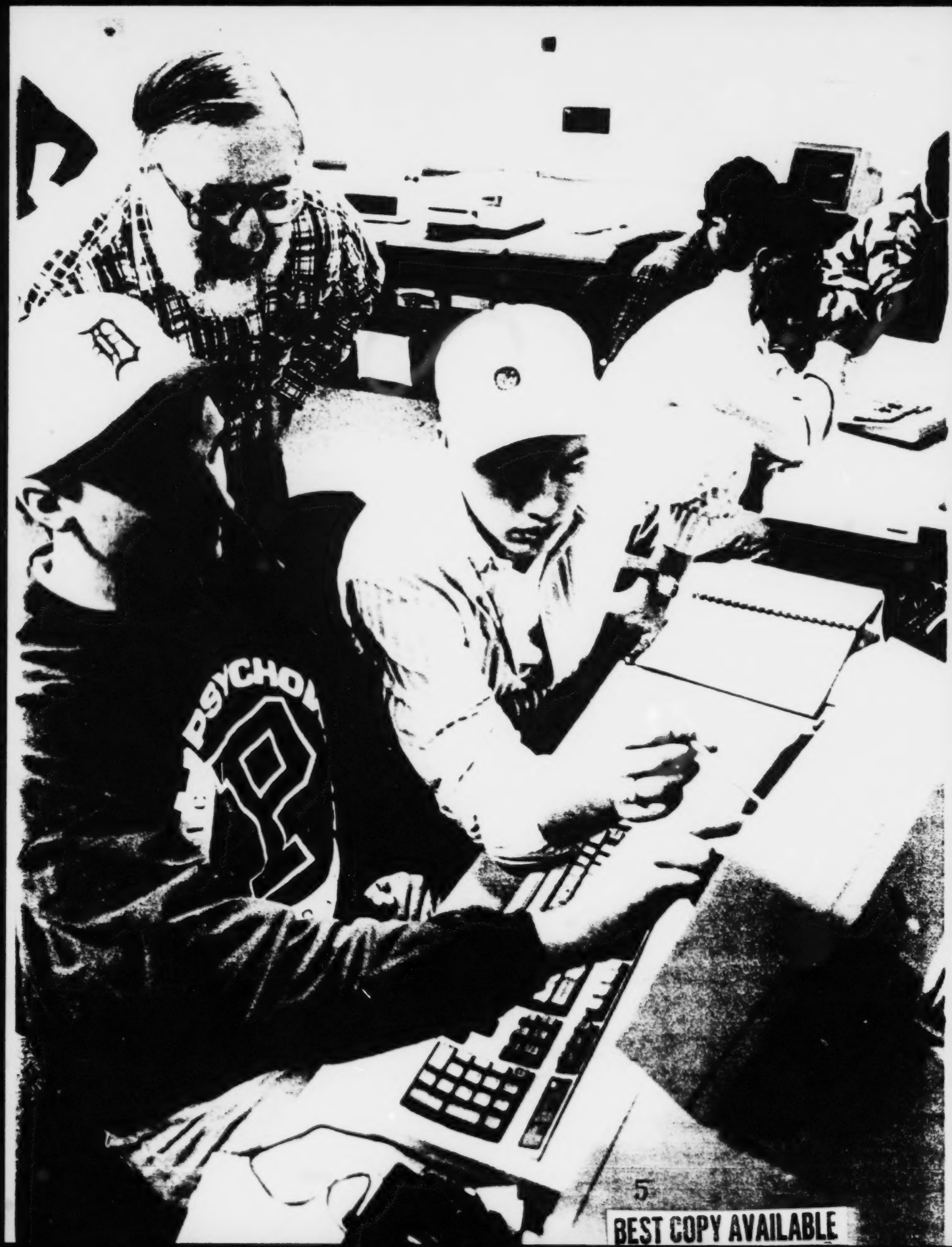
The activities described in this report are a representative, but incomplete, selection of educational projects supported by the National Science Foundation, 1981-1991.

NSF NOW



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The National Science Foundation
Washington, DC

First in the World in Mathematics and Science

The national education goals adopted by President Bush and the nation's governors present us with an extraordinary challenge: **"By the year 2000, U.S. students will be first in the world in science and mathematics achievement."**

The effort to make the United States number one in math and science achievement must reflect the diversity of our country and our democratic approach to education. Everyone, not just a select few, must reap the benefits of our efforts to provide a world-class education to our students.

There are many reasons for seeking to provide a world-class education. One reason is that education is important for its own sake. But education for its own sake is not as compelling an argument for government support as is the fact that a world-class education system is essential if we are to improve our standard of living and the quality of life on our planet.

Being number one means that school children, their parents, college students, and the public at large appreciate that learning is often hard work and that it requires effort and commitment and persistence.

Being number one means that we understand how to individualize instruction to accommodate different skill levels and the needs of a diverse population.

Having a world-class education system means that we view the educational process not as something isolated from the rest of life, but rather as a central part of life.

We will know we are number one when it is widely accepted that our society will never be better than our schools and when other countries look to us for techniques to improve their own education systems. We will know we are number one, not when the debate over how best to educate Americans subsides, but when it becomes a concern of every citizen—those with children in school and those without. Finally, we will know we have succeeded when people recognize that their formal years in school are just the beginning of an educational process that must last a lifetime.

The National Science Foundation's education and human resources programs are committed to the achievement of these fundamental education goals.

Walter E. Massey

Walter E. Massey
Director

Introduction

The Foundation's Commitment to Education

NSF began the decade with a vision articulated in its report, **Educating Americans for the 21st Century**:

"The plan is not only for the affluent or gifted . . . every child can develop an understanding of mathematics, science, and technology if appropriately and skillfully introduced at the elementary, middle, and secondary levels."

Since 1950, the National Science Foundation has supported education and research in science, mathematics, and engineering. NSF's support of research helps ensure orderly and sustained expansion of knowledge in these fields. Its support of education makes possible the training of future scientists, mathematicians, and engineers. Equally important, NSF's support of education promotes general scientific literacy, making us better prepared, individually and as a nation, for the scientific and technological challenges ahead.

In the early 1980s, national leaders began sounding the alarm about an impending crisis in education. Since then, studies and reports have documented a growing awareness of and an increased sense of urgency about weaknesses in how the United States educates its citizens.

These reports painted an especially bleak picture concerning mathematics and science education. A 1983 report by the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology proclaimed, "The Nation that dramatically and boldly led the world into the age of technology is failing to provide its own children with the intellectual tools needed for the 21st century."

The Last Decade

In response to this alarm, a dramatic series of changes took place at NSF during the 1980s regarding education priorities and activities. The NSF Directorate for Education and Human Resources initiated a comprehensive examination and revitalization of U.S. science and mathematics education.

From 1981 through 1991, NSF designed and began development of a new generation of education and human resource programs. This decade of design and development became possible in large part because Foundation funding for education increased from $26 million in 1982 to $465 million in 1992.

Since 1981, NSF has put much of the basic research in place to understand teaching and learning. The Foundation has engaged in comprehensive and systemic reform in mathematics and science education. It has fostered development of materials and techniques with the success of all, rather than a few, students in mind. It has assembled a portfolio of teacher preparation and teacher and faculty enhancement programs. It has implemented K-12 and undergraduate student-focused activities, along with graduate education, informal science education, and human resource development efforts. Governing these efforts is the fundamental view that all segments of the population must be engaged in science and mathematics learning if we are to ensure that all Americans will enjoy an enhanced quality of life in a global, technological society.

The Investment in Education

Building on more than four decades of knowledge and experience, NSF today is able to provide vigorous leadership in the nation's efforts to strengthen science, mathematics, and engineering education.

NSF programs testify to the talent and effectiveness of committed researchers and educators throughout the country who work with Foundation staff to produce exemplary materials and models to help the nation attain its education goals.

Today, more than 20,000 kindergarten through 12th grade teachers and more than 6,000 college and university faculty are directly involved in NSF education projects. An impressive range of activities is under way in elementary, middle, and senior high schools; in undergraduate classrooms; in graduate science and engineering laboratories; in museums and science centers; and in hundreds of other settings across the United States.

The nation can now capitalize on NSF investments by using as leverage the reach and scope of Foundation education programs so that the wide array of benefits they offer can help us achieve the national goal of excellence in mathematics and science education.

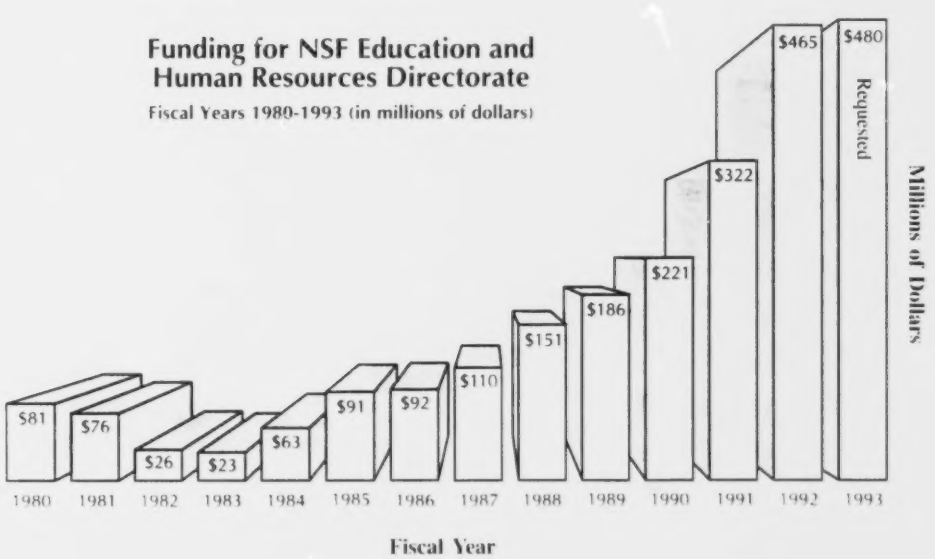
The following pages briefly describe the diverse and vigorous education and human resource programs the Foundation has developed and supported over the last ten years—activities that reach out to all, recognizing the needs of a changing U.S. population and a changing workplace.

"We must return to basics, but the 'basics' of the 21st century are not only reading, writing, and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy—the thinking tools that allow us to understand the technological world around us."

Educating Americans for the 21st Century
National Science Board
1983

Funding for NSF Education and Human Resources Directorate

Fiscal Years 1980-1993 (in millions of dollars)



Teachers and Faculty

Teachers and faculty at all levels are a national resource. They nurture early interest, promote exploration, and develop career aspirations. NSF sees today's teachers and faculty as essential to both short- and long-term success in revitalizing science, mathematics, and engineering education.

To strengthen this resource, NSF funds professional development courses for thousands of elementary, middle, and secondary teachers and college and university faculty. The Foundation also funds model projects that demonstrate how to teach mathematics and science effectively from kindergarten to 12th grade and through the undergraduate years.

NSF programs are committed to dramatically improving many aspects of instruction. These programs provide support systems for classroom teachers, enhance the quality of education for future teachers, increase the pool of qualified professionals who will teach in the classrooms of the future, and help provide institutional rewards for faculty who teach in colleges and universities.

The Foundation's broad-based investment in the nation's cadre of teachers and faculty emphasizes collaborative approaches. Each year, NSF funds workshops that offer kindergarten through 12th grade teachers opportunities to study at colleges, universities, and research laboratories and centers. Additionally, kindergarten through 12th grade science and mathematics teachers are selected for Presidential Awards each year in a program that is establishing a large pool of teachers who serve as models and who are empowered to interact with business and community leaders.

Individuals in higher education are linked with others from associations and research organizations. They jointly develop new ways to attract women, minorities, and persons with disabilities into teaching mathematics, science, and engineering.

From 1984 to 1989, NSF invested $160 million in more than 600 *Teacher Enhancement* projects, involving more than 63,000 science and mathematics teachers in all regions of the country.

- 18 percent of all participants were members of minority groups.
- More than 50 percent of all participants were female.

These projects secured almost $80 million in additional funds from other sources and "in kind" contributions.

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■ **Presidential Awards for Excellence in Science and Mathematics Teaching**

NSF's undergraduate faculty programs are designed to stimulate and motivate educators to devote greater creative energy to the teaching/learning process. A program for undergraduate faculty funds seminars, short courses, workshops, and other activities. Participants learn about new developments in their fields and apply this new knowledge in their teaching.

"My life has changed tremendously because of the national involvement I've had. I now can share more effectively with my colleagues as we try to make American students number one.

"Another thing is that I'm a better role model for my students. Most children like mathematics until middle school. We lose them in the middle grades. These are critical years to recapture interest and get them on track for ninth and tenth grade algebra.

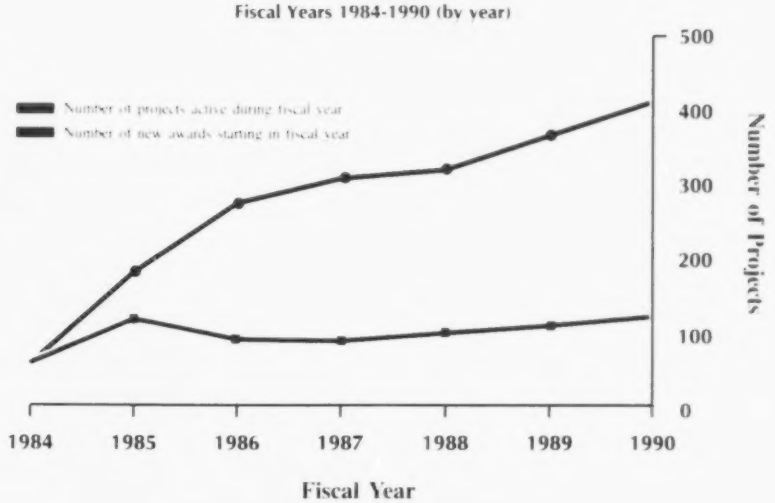
"I tell my middle school students that I can identify with their frustration with mathematics. I tell them I can see what they will become at the end of the year. I tell them, 'If you excel in mathematics, then you can make a difference in the world.'"

Larry Williams
Presidential Awardee
Eastwood Middle School
Tuscaloosa, Alabama

In November 1990, NSF sponsored a colloquium on undergraduate engineering, mathematics, and science education involving 53 Presidential Young Investigators. This group's interest in education is notable because its members are among the most visible and promising of the beginning faculty at the nation's research universities. Colloquium participants produced a report, **America's Academic Future**, that outlines a vision for the year 2010 to help guide NSF in its higher education programs.

Number of NSF Teacher Enhancement Projects

Fiscal Years 1984-1990 (by year)



Teachers and college faculty comment on NSF workshop experiences:

"The whole curriculum at my school opened up. I started new courses that I never would have attempted without this workshop."

"I was such a traditional teacher before this. Now I'm more problem oriented and not tied to the book. The kids ask more intuitive questions, not 'What's the formula?'"

"It's been awhile since this summer's NSF oceanography short course and I'm still 'fired up' about the entire experience. I know of no other way that I could have learned so much on-site and up-to-date oceanography."

"The mathematical content was substantial. It is surprising how much sophisticated material can be taught to undergraduates in an elementary but mathematically honest way."

The Foundation is committed to renewing the important educational role of community, junior, and technical colleges. It recognizes that many minority students begin their college careers at two-year colleges, making these institutions critical links in the science/mathematics/engineering pipeline.

"NSF funded a workshop where key people representing mathematics, science, and engineering—administrators, deans, and others—deliberated the major two-year college issues, including curricular reform and faculty turnover. By supporting the workshop, NSF helped us to move on defining our issues and identifying leaders.

"Most of the recommendations we made to NSF have already been implemented. One significant result is that NSF committed to have two-year faculty on each appropriate review panel. This is new, and now the two-year college faculty will better understand the larger system."

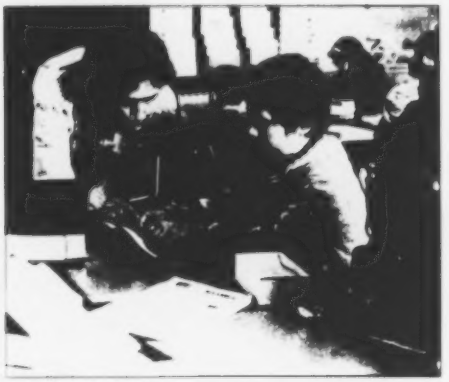
Dale Ewen
Parkland College
Champaign, Illinois

Past President
American Mathematical Association
of Two-Year Colleges

Since 1989, National Geographic *Kids Network*® has reached more than 4,000 classrooms and involved 300,000 students throughout the United States and in many other countries. Using hands-on techniques, this project enables fourth through sixth grade students to learn about scientific concepts by dealing with scientific problems. It frames material in real-world terms and heightens awareness of social issues facing local and global communities. Students collect scientific data in their homes and feed it into a national, electronic network, communicating with other students and scientists across the country.

"The very magic of National Geographic Kids Network® *is that it integrates so many things. Somehow the sum is greater than the parts. It combines telecommunications, which provides instant responses, with geographic scope and motivation. It offers all that we know is effective from research—collaborative learning, interdisciplinary work, looking at science in the context of real-world needs—and is easy to use even though the work is similar to what adults do. It prepares kids for a new kind of workforce."*

Monica Bradsher
National Geographic Society



Project IMPACT—Increasing the Mathematical Power of All Children and Teachers—is a joint venture between the University of Maryland and Montgomery County Public Schools. It gives teachers special help in communicating mathematics to elementary students at schools with high minority enrollments. The teachers bring hands-on tools and word problems into classrooms where students engage in group work. The teachers and students discuss how to approach problems and the various ways they can go about solving them. To refine their methods, teachers receive two summers of training and support from mathematics specialists during the school year.

"Our teachers do not teach the same ways they did when we started working with them. And they say that they will never go back to their old methods. They used to tell students how to solve problems, which makes math become a collection of rules to be remembered. In Project IMPACT, teachers do not want mathematics to be a bunch of rules. Even young children can find patterns in the world around us and, with their teachers, construct ways to symbolize and represent the relationships they recognize. We are building on the mathematics that the child already knows. These children do not expect their teacher to tell them how to solve a problem, rather they discuss the problem with their teacher. Our teachers will say to their class, 'Tell me your thinking.' Then the students will tell how they thought about the problem and how they solved it."

Patricia Campbell
University of Maryland at College Park

The American Chemical Society's *Chemistry in the Community (ChemCom)* illustrates a positive collaboration between a professional society and the education community in producing a high school course that presents basic principles of chemistry in light of societal problems. The students enrolled are not necessarily planning to pursue careers in the sciences, but they often do as well as college preparatory students on routine chemistry test items and better on items about social/environmental issues. Since 1987, an estimated 250,000 students in all 50 states have benefited from the use of *ChemCom* materials.

A project at Columbia College, Princeton University, and Indiana University developed a freshman chemistry course that centers on environmental issues and that emphasizes hands-on, exploratory activities. The course is designed to attract non-chemistry majors.

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Classroom and Laboratory Tools

What students **do** in classrooms and laboratories significantly influences what they **learn**. Students are stimulated by actively participating in the process of scientific discovery. The appropriate curricula and tools help students learn scientific relationships. Used in imaginative ways, innovative materials motivate students to reason mathematically and scientifically and to explore creatively the technological world in which we live.

Biological researchers at the University of Wisconsin, Madison, have developed a unique cabbage-related plant that completes an entire life cycle (going from seed to seed) in 35 days. Originally developed for research purposes, these plants soon became a learning aid for students of all ages. The *Fast Plants* packages include plants and instructional materials for elementary through college students. The packages are low in cost and accessible to students of all interests and abilities. Three years after development, nearly 10 percent of all high schools in the United States were using these tools in their biology programs.

NSF is funding *MathFINDER CD-ROM*, a project using CD-ROM technology to catalogue an extensive amount of existing mathematics curricular materials. More than 1,300 mathematics lessons are being classified and cross-referenced according to the **Curriculum and Evaluation Standards for School Mathematics** developed by the National Council of Teachers of Mathematics (NCTM). This presentation allows teachers access to material by grade and ability levels, as well as by the **Standards**. For example, a teacher can find lessons to help sixth graders systematically collect, organize, and describe data.

*"We hope this project will do two things. It will make the [NCTM] **Curriculum Standards** real for teachers because, from 15,000 pages of text, we found illustrative examples for each bulleted item in the **Standards**. We see it as a tool in standards implementation, in changing mathematics education, and we also see it as a tool for preparing teachers and for developing new materials."*

Mark Driscoll
Education Development Center

NSF is actively shaping a new generation of instructional materials, consisting not only of books, but also of videotapes, videodiscs, hands-on tools, and laboratory equipment. In design and use, these materials reflect sound teaching strategies and contribute to effective learning environments. They also incorporate the use of computers and telecommunications to help prepare students for the next century's world of work.

Curriculum materials and laboratory tools supported by the Foundation reflect the recent development of national standards in mathematics and the necessity of incorporating hands-on approaches into science.

Moreover, by using women, minorities, and persons with disabilities as role models, these materials highlight contributions by people from groups underrepresented in scientific fields. By overrepresenting these groups in field tests of new materials, developers help demonstrate that the materials are effective in engaging all individuals in the conduct of science. Through the use of such strategies, NSF-supported materials help improve science, mathematics, and technology instruction for all students—from pre-kindergarten through graduate school.

Modern laboratory instrumentation allows students to explore phenomena and to experience science as it is actually practiced in the workplace. Over the last seven years, NSF has supported about 6,500 faculty in every state to enable them to share in the design of undergraduate laboratory activities using the latest equipment. An external evaluation of the program's first three years reported that the activities had major positive effects on student learning and faculty enthusiasm. It also found that other resources—equivalent to more than four times the NSF level of support—were attracted to the projects.

Within the last three years, NSF has supported a nationwide movement to update calculus teaching. This NSF program makes learning calculus a hands-on experience, with an emphasis on comprehension rather than rote calculation. NSF has made it possible for some 2,000 instructors to participate in this effort. This reform initiative, as many education leaders have come to say, aims to make calculus "a pump, not a filter" for college students. A common feature of these new approaches is that students have more opportunity to learn through exploration and group activities.

Students comment on an innovative calculus course, part of an NSF-funded program at the University of Illinois:

"I can't imagine taking a math class in a normal fashion again."

"It gave me a real feeling that I was actually doing something, not just plugging and chugging away."

"I like the course because we have electronic notebooks which means we have infinite sets of examples. I cannot learn from one example as in the traditional class."

"Too many calculus classes try to get students to memorize procedures. We don't lecture. We don't use any standard text materials. The delivery is strictly through our electronic-interactive text. We try to set up examples and visualizations on the computer in order to get an idea into the students' heads before we talk about it. We talk with the students once a week in a classroom setting. But the students do their own work, at their own pace. We turn the students loose. Instead of sinking, they swim."

Jerry Uhl
University of Illinois
Urbana-Champaign

Eight projects—two at the elementary level, five for middle school, and one for high school—are building on the new NCTM **Curriculum Standards** to create comprehensive, multi-year mathematics curricula. Along with other projects, these efforts will provide the next generation of instructional materials in mathematics for kindergarten through 12th grade, materials that meet the world-class standards being set for American education.

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Applying Technology to Education

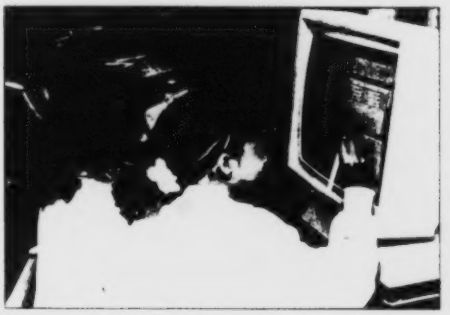
In the early 1980s, NSF began supporting work at the Technical Education Research Center (TERC) on microcomputer-based laboratories. As a result, sensors, probes, and other instruments now exist for the computer systems most commonly found in American classrooms and are used extensively to engage students—from elementary grades through college and beyond—in the discovery of science and mathematics.

Technology, in a wide variety of forms, has the potential to augment—by orders of magnitude—student capacity for learning. Moreover, the rate at which educational technologies are being developed makes it likely that within ten years, science and mathematics learning will include subject matter and teaching strategies that cannot yet be envisioned.

NSF is working to anticipate and accommodate the trajectories of future technologies in two distinct ways:

- Setting goals, sharing information, and defining research for new educational technologies, new curricula, and new educational delivery systems over the next decade.
- Accelerating the introduction of revolutionary computer and telecommunication technologies into science and mathematics instruction.

Advances in software development and artificial intelligence are creating many possibilities. "Intelligent" computer tutors respond to the needs of individual students, building on prior knowledge and even accounting for misconceptions. Further development of technology will result in new materials becoming more affordable, and therefore more accessible, to all students in all parts of the country.



The *SHARETEXT* project has created a network of teachers who use communications technologies to share information and methods to enhance their classroom activities. The project has also published precalculus materials that focus on the NCTM **Curriculum Standards**.

"We are bringing together change makers in their schools and creating long distance colleagues. We have created support systems for each other with our computer network and with a quarterly newsletter. The money we got for this project allowed us to get organized, and now that organization has turned into more opportunities.

"With SHARETEXT, *the teachers also have strategies and materials which allow the students to use technology effectively to learn mathematics. Technology is not an add-on. It's an essential tool. The reason teachers are attracted to* SHARETEXT *is that they have questions in their classrooms which they can't answer. Group work and long-term projects are also part of our classrooms."*

Helen Compton
North Carolina School of Science and Mathematics

Sharing Information

The Foundation has recently been exploring ways to use both *NSFNET* and its successor network, *NREN (the National Research and Education Network)*, in science and mathematics education. By the end of the decade, *NREN* will link students, teachers, and practicing scientists throughout the nation. By helping individuals and groups share information, resources, and talent, these technologies speed collaboration and innovation. By supporting data-sharing across the country and even around the world, *NREN* will give all students, on a daily basis, opportunities to share in the process of scientific inquiry that only a few now enjoy. With electronic networks, students of all ages and in all parts of the country can conduct original scientific research and create new learning experiences that are not possible in individual classrooms.

To offer teachers easy access to a vast array of classroom materials, the Foundation is developing an electronic database of instructional materials. Ready access to new developments in science and mathematics education means that all students and teachers, rather than only those located near field trials, can soon reap the benefits of NSF-funded programs.

Over the last 20 years, NSF has supported the development of Logo, a computer programming language developed by Wallace Feurzeig and Seymour Papert. This language, which involves the manipulation of a "turtle" to create simple programs, has opened up the exploration of geometric ideas to very young children. Along with other applications, Papert combined Logo with the popular LEGO® toys to create a unique laboratory for young students to test scientific principles and learn mathematics. Logo allows them to write computer programs to assemble complex moving devices with building blocks and sensors. By constructing a working elevator with a light sensor to control direction, for example, students gain a basic understanding of gears, switches, and simple programming.

Logo now exists in some two dozen versions, in eight foreign languages, and on 13 different computer systems. Its impact on education is felt worldwide, and it is becoming a model for research and development in the use of computers for mathematics and science education.

The Adventures of Jasper Woodbury, developed at Vanderbilt University, is an elementary mathematics program that uses videodisc technology to develop students' critical problem-solving and reasoning skills. A study of more than 700 students in nine states found that those who used the *Jasper* materials showed improved understanding of basic mathematical concepts and performed significantly better on word problems and multi-step problems.

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Learning How People Learn

Many mathematics and science classrooms today look and feel much different than they did in the past. Some of these changes are the result of studies of the dynamics of minority student performance in pivotally important freshman calculus and chemistry courses. Uri Treisman's project at the University of California, Berkeley, and JW Carmichael's work at Xavier University of Louisiana, for example, point to the importance of placing collaborative group work, immersion learning, and explicit instruction in problem-solving at the core of freshman instruction. These projects also demonstrate that when freshman courses provide a sense of community and a glimpse of professional life, students are likely to succeed.

Students bring to the classroom their knowledge and their ways of organizing that knowledge. Gender and culture influence learning styles as well. Research shows that when curriculum and instruction are tailored to fit the different resources and orientations students bring, learning improves—and so does student satisfaction.

NSF-supported research suggests new ways to improve science, mathematics, and technology education by clarifying how learning takes place and by describing what kinds of environments promote it. Research in teaching and learning indicates what kinds of classroom and laboratory materials work best and how teachers and faculty can effectively communicate science and mathematics to students of all ages and backgrounds.

By changing learning cultures and environments, NSF-supported educational research is showing ways to increase the number of women, minorities, and persons with disabilities studying science and mathematics.

Research also demonstrates how to productively connect mathematics and science instruction to other course work in language, geography, and history, making mathematics and science more familiar and relevant to students—and thus improving their scientific literacy.

Benefiting from Technology

NSF leadership has helped show how to more effectively use classroom technologies—calculators, computers, and video equipment—to enhance and supplement lectures and recitations and allow students to **experience** science through hands-on experiments, interactive approaches, and group learning.

Technology is used well when treated not as peripheral to instruction, but rather as integral to student learning. Properly implemented, technology allows a student to **apply** principles to specific, tangible situations. This approach encourages students to focus on the **process** of problem-solving rather than on its result. Instead of facing situations that lead to either success or failure, students experience situations with a variety of possible outcomes, each offering opportunities for learning.

Alternative Ways of Assessing What Students Learn

NSF is working to make assessments into tools that inform instruction and improve the overall quality of science and mathematics education. New curricular and teaching goals require new ways of assessing student learning. Innovative assessments emphasize conceptual knowledge, problem-solving ability, and higher-order thinking skills whereas traditional testing, including standardized tests, tends to measure recall and low-level concepts—providing an incomplete portrait of students' understanding.

For these reasons, NSF is supporting several major projects that aim to better understand student learning. These range from studies on the role of tests in state and national policymaking to the development of assessments that are integral to mathematics and science classroom materials.

Cognitively Guided Instruction (CGI) is an NSF-funded program at the University of Wisconsin that works with elementary teachers to discover what they know and what they believe about how young children learn mathematics. By investigating what impact teachers' knowledge and beliefs have on classroom instruction, researchers are gaining a better understanding of how students can learn to their greatest potential. These studies are ongoing with kindergarten through third grade students from a diverse range of ethnic backgrounds.

"But what really, really convinced me [about CGI] was working that first year with my kids in the first grade, and the more problems I asked, the better they got. The more I challenged them, the better they got. . . . It was the students who convinced me that CGI works, and they went far beyond what I ever expected that they could do."

Mazie Jenkins
Lincoln Elementary School
Madison, Wisconsin

Investigators at Boston College are examining the impact of mandated testing, both standardized and in textbooks, on the materials and teaching of mathematics and science. Preliminary results from this study indicate that existing tests fail to assess important content and skills. Researchers found that in science tests, for example, fewer than 25 percent of all items assessed higher-level concepts or scientific procedures. In mathematics, fewer than 5 percent of all test items surveyed required higher-order thinking or problem-solving skills.

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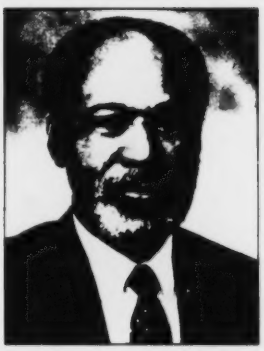
The National Science Foundation
Washington, DC

Through The Year 2000



For the remainder of the decade and into the next century, our nation faces both challenge and opportunity in science and mathematics education. A national consensus has emerged that the United States must renew and improve its science and mathematics education enterprise.

For the decade from 1992 to 2001, the Foundation has outlined a vigorous agenda for stimulating change in mathematics and science education in order to improve performance at all levels for all students.

The next decade of NSF educational achievement will be one of widespread dissemination and implementation, as outlined on the facing page. The agenda for the next decade recognizes that our greatest challenge is to ensure access to high quality science, mathematics, and engineering education for all.

This agenda recognizes that our greatest assets are: students of all ages—kindergartners through postdoctoral students; teachers in various school settings throughout the nation; scientists working in all the enterprises that make up the American research, education, and business communities; and citizens who want to know more about the world we live in—and who want to be knowledgeably involved in the many critical, scientific choices we make each day.

To this end, for the next decade we are placing great emphasis on teachers and faculty, on classroom activities, and on initiatives within cities and states.

Our ultimate goal is to create and sustain a national atmosphere that values and encourages scientific thinking and scientific endeavors by all of our citizens. When we succeed, **every** student will be able to study mathematics and science and become knowledgeable in these vital areas.

Now we are building upon the past decade of achievement by embarking on a period of intensive evaluation and dissemination. By determining the extent to which our various programs have reached their announced goals, by assessing the quality of the accomplishments of those programs, and by making readily available the best products of those programs, we will be well positioned to assist science educators across the United States in their reform initiatives. In the next decade, we envision a society in which all segments of the public regard science, mathematics, and technology as useful and relevant to their daily well-being.

I invite your involvement during the next ten years as we build upon the best of what we have learned and as NSF education programs help the nation achieve world-class standing.

Luther S. Williams

Luther S. Williams
Assistant Director for Education and Human Resources

NSF Education Goals

The Next Decade of Achievement

Helping Individuals

- Support teacher preparation and teacher career development.
- Renew the motivation for creative teaching at institutions of higher education.
- Increase competence, creativity, and confidence in mathematics and science among students from kindergarten through college.
- Promote and sustain interest and excellence among undergraduates, graduate students, researchers, and fellows.
- Support development of materials and strategies that will increase the number of students—particularly women, minorities, and persons with disabilities—who pursue continued study of science, mathematics, and technology.

Providing Support

- Fund development of science and mathematics materials that reflect national standards, support laboratory learning at all levels in all areas of science, and serve students of all interests, backgrounds, and abilities.
- Generate knowledge of the processes that comprise teaching and learning, including the assessment of student learning, in order to strengthen curricula, give teachers tools to guide instruction, and inform future efforts in science and mathematics education.
- Promote K-12 systemic reform at local and state levels.
- Expand program evaluation efforts and dissemination of products and project/program outcomes.
- Produce dynamic curricula for college and university classrooms.
- Develop strategies to facilitate the transitions from high school to undergraduate settings, from two-year to four-year colleges, from undergraduate to graduate study and into the workplace.
- Provide examples, catalysts, and resources in informal education settings to support mathematics and science education.

Involving Others

- Improve the science literacy of adults so they can make informed, responsible decisions about the environment, medical research, energy, and other science policy issues that have implications for everyone in our society.
- Encourage parents and other adults to become informed advocates for higher quality and more universal education in science and mathematics, and to support their children's science and mathematics endeavors at home and elsewhere.
- Foster collaborative projects and reform activities reaching across educational constituencies, subject areas, and states.
- Stimulate professional associations to join with NSF in meeting the nation's educational challenges.

Leadership and Systemic Reform

In response to Congressional concern 13 years ago, NSF began a program to further stimulate the research capabilities of academic institutions in those states with less competitive research structures. *The Experimental Program to Stimulate Competitive Research*, called *EPSCoR*, has increased research capacity and helped create synergy among state leaders in public policy, science, government, academia, and the private sector. Recognizing its success, Congress has cited this program as a model for similar endeavors in other federal agencies. The Commonwealth of Puerto Rico and these 18 states are currently eligible to participate in *EPSCoR*: Alabama, Arkansas, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming.

Many Foundation education activities also serve to identify and develop leaders who are ideally located to help bring about systemic reforms in education. Systemic reform depends upon linked efforts across the various educational levels and between education and other sectors.

Some educators participate in specific NSF leadership development programs. Leadership programs can help them to see links between classroom activities and workplace needs, can bring together high-level research endeavors and the content of school curricula, and can help assure teachers and faculty of the support needed to introduce meaningful change into mathematics and science classrooms.

Other educators who contribute to systemic reform take advantage of teacher enhancement programs or other NSF education activities. Regardless of the activities they choose, all who participate receive the added benefit of becoming change agents and advocates for effective and long-lasting reforms.

State Systemic Initiatives

State-level initiatives are an important way to reach the more than 15,000 school districts that make up the nation's diverse school system. Systemic and lasting educational improvement in the United States depends on state policies, state adoption of texts and curricula, and state human resource practices. Strong state education programs and policies are vital links between national education goals and classroom implementation of the practices that will help us achieve these goals.

By the end of Fiscal Year 1993, NSF expects that about 25 states will be participating in the *Statewide Systemic Initiatives (SSI)* program. This program is designed to help states strengthen their education systems and implement comprehensive, rather than piecemeal, reforms. *SSI* projects coordinate curriculum, instruction, assessment, and teacher preparation. They facilitate collaboration among educators, public policymakers, parents, and members of the science, mathematics, and business communities.

Leadership Initiatives

For the past decade, Foundation-sponsored programs have created teams that match teachers, faculty, and other educators with local business and industry representatives and with local and national public policy experts. Leadership programs have likewise brought research scientists together with curriculum planners and school district representatives to help bridge the gap between what happens in the lab and what happens in the classroom.

"What encourages me most about leadership training is that people are starting to see science as the driver of curriculum. Through science, children can learn to read and write. Instead of being an add-on, it can lead the elementary school curriculum.

"The best part about the [leadership] institutes is the sharing. The teachers are not isolated. People at all levels—administrators, scientists, science coordinators, teachers, business people—see the power of science. At an institute, you're dealing with a small group that will affect hundreds of thousands of children. Those people have the commitment and the authority to do something."

JoAnn DeMaria
Presidential Awardee
E. Barbour Hutchison Elementary School
Fairfax County Schools, Virginia

Number of Teacher Enhancement Projects by Region

Fiscal Years 1981-1990

"We are using some of the SSI money to coordinate lower and higher education with business, industry, and other entities—to be an advocate for education interests and to coordinate and provide public support for the diverse education change efforts in curriculum, teaching, and assessment.

"There are five components to our grant. One, the creation and establishment of the Connecticut Academy of Education in Science, Mathematics, and Technology, will coordinate our work. Second, we are giving grants to the 25 most needy school districts to focus on adoption of nationally recognized, and frequently NSF-funded, materials. Next, we are promoting dialogues between teacher preparation and liberal arts faculty and between university and high school people, with accompanying grants. Fourth, we're using science institutions—museums and so forth—that provide important support to teachers and students. In this area, we're working with the Hartford Association of Black Churches. Last, our public awareness arm has connected Connecticut Public TV, The Hartford Courant, and the largest commercial TV station in the state to launch a campaign about changing beliefs."

Steven Leinwand
Connecticut Department of Education

Beyond the Classroom

Girls, Inc., has developed *Operation SMART*, a national program of out-of-school activities emphasizing hands-on experiences in mathematics, science, and technology for girls ages 6 to 18. More than 80 affiliates of Girls, Inc., operating more than 150 centers, are currently implementing *Operation SMART* through after-school, weekend, and summer programs. These programs have reached more than 250,000 girls nationwide.

The Foundation is concerned about the full educational spectrum—from preschool to graduate school, as well as life-long learning. Through informal education projects, NSF offers stimulating opportunities to individuals of all ages—opportunities that spark interest and further an understanding and appreciation of science and mathematics.

The Foundation's informal science program funds projects reaching urban and minority youth through alternative science education experiences. It also supports research on the educational benefits of out-of-school science experiences.

NSF fosters projects that integrate in-school and out-of-school activities. Out-of-school projects involve commercial and public broadcasts, film and print media, science and natural history museums, science-technology centers, aquaria, nature centers, zoological parks, science clubs, and various community-centered activities. Most informal science projects reach large audiences and have significant regional or national impact.

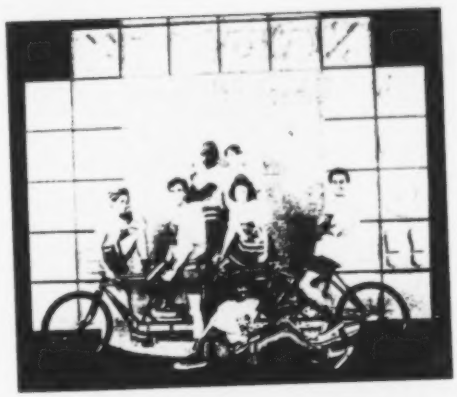
Reaching Out Through Collaboration

Many NSF initiatives promote the sharing of resources. The *Exhibits Research Collaborative*, for example, pools expertise and resources from eight science centers across the country. A prototype of each exhibit is developed and tested at one museum site with input from member institutions, and then circulated among all the members, reaching audiences from Charlotte, North Carolina, to Portland, Oregon. Such collaboration and outreach to larger populations are now expected of all exhibit-based projects supported by NSF.

"Exploring, like doing basic research, is often fruitless. Nothing comes of it. But also like basic research, as distinct from applied or directed research, exploring enables one to divert attention from preconceived paths to pursue some intriguing lead: a fragrance, a sight or smell, an interesting street or cave, an open meadow encountered suddenly in the woods or a patch of flowers that leads one off the trail, or even a hole in the ground . . .!

"The whole tradition of exploration is being lost for entire generations. It is, therefore, more important than ever that museums assume the responsibility for providing the opportunities for exploration that are lacking for both city and suburban dwellers."

Frank Oppenheimer
(1912-1985)
Founder, Exploratorium, San Francisco



NSF-funded instructional materials delivered by television are reaching very large numbers of students, both at home and in school. *Reading Rainbow* is a television series that uses books as a platform for introducing a wide range of concepts and ideas, including scientific topics, to its viewers. A survey during the 1990-1991 school year identified *Reading Rainbow* as the television program most frequently used in schools. It was estimated that the program reaches more than 130,000 teachers and 4 million students annually.

Children viewing *Square One TV* have shown significant gains in problem-solving and generally improved attitudes toward mathematics. These positive results and others occur among both boys and girls from different racial and ethnic groups and from diverse socio-economic backgrounds. On the air since 1987, *Square One TV* reaches some 800,000 viewers daily at a cost of about 6 cents each.

"We expand a kid's view of math from computational arithmetic to topics such as probability, statistics, and combinatorics—very unusual material for eight-year-olds. We try to help kids make the connection between school math and street math—to give them some way to tie together and transfer what's been learned in the classroom.

"Looking at the mathematics education reform movement from a broad perspective, Square One TV is an informal component delivering a great deal of information to a very broad audience."

Joel Schneider
Children's Television Workshop

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Increasing Diversity

The nation is changing in two major ways. It is becoming more dependent on technology and more ethnically diverse. These two facts underscore the necessity of bringing about a convergence of needs and talent.

Many of the most vital domestic industries—computers, semiconductors, synthesized materials, and biotechnology, for example—depend on workers with scientific and technological skills. In the past decade, the employment of scientists and engineers has grown three times faster than total employment and twice as fast as all professional employment.

The Challenge of a Changing Society

Over the next 30 years, minority students will increase from one-fourth to almost one-half of the total number of school-age children. Collectively, women and minority students will constitute nearly three-fourths of all students in our elementary and secondary schools.

By the year 2000, a substantial percentage of new entrants to the nation's workforce will be women, members of minority groups, and persons with disabilities. However, these groups typically have been underrepresented in occupations that require training and expertise in the sciences and mathematics.

The *Career Access Opportunities in Science and Technology (ACCESS)* program supports Summer Science Camps, Partnerships for Minority Student Achievement, and Comprehensive Regional Centers for Minorities. *ACCESS* enhances the kindergarten through 12th grade science and mathematics preparation of underrepresented students in an effort to increase the number of students prepared to enroll and succeed as science, mathematics, and engineering majors in college.

Alliances for Minority Participation (AMP) is a major new Foundation initiative that brings many forces to bear in a concerted effort to increase the number of science and engineering degrees granted to underrepresented minorities. Six universities—The University of Alabama at Birmingham, Arizona State University, the University of California at Irvine, Jackson State University, Texas A&M University, and the University of Puerto Rico—work in cooperation with other universities, community colleges, national laboratories, government agencies, and private companies.

Linking high school to college, two-year to four-year colleges, and undergraduate to graduate school, *AMP* merges education and research into a seamless effort to boost the number of minority scientists and engineers.

Benefiting from public/private partnerships and leveraged resources, these alliances will help the Foundation reach its goal of increasing minority undergraduate degrees in natural sciences and engineering by the year 2000—to 50,000 annually from the current total of 13,000 B.S. degrees, and to 2,000 Ph.D.s in science and engineering from the current rate of about 350 annually.

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Meeting the Challenge

Since the late 1980s, NSF has accelerated its efforts to increase the number of women, underrepresented minorities, and persons with disabilities who pursue scientific and engineering careers and majors.

Various NSF programs are designed to support this goal. These programs focus on student and teacher development, the establishment of learning environments that effectively nurture the talents of members of all underrepresented groups, and the operation of targeted initiatives to remove barriers affecting these segments of the population.

A comprehensive set of programs, designed to specifically address the needs identified for minority individuals, exists at three levels—precollege, undergraduate, and beyond.

The centerpiece of this coordinated effort for minorities is the Foundation's trio of human resource development initiatives: *Career Access, Alliances for Minority Participation,* and *Research Careers for Minority Scholars.*

Similar programs are being planned for women and persons with disabilities.

Thirty-five colleges and universities participate in the *Research Careers for Minority Scholars Program.* These projects help to enhance academic climates for minority students by enabling faculty, staff, and students to work together to make undergraduate degree programs in science, mathematics, or engineering more productive experiences.

In the first two years of this program, the participating institutions retained 93 percent of their scholars. By the end of 1992, more than 500 students will be involved nationwide.

"This program not only gives the students financial help, it lets us give them staff support. We work with them on problem-solving in teams so that they learn to work together, not just compete with each other. Our students become positive.

"We attract students because they receive support and praise, become part of a community. We stress that tutoring is for someone who wants to get A's. We monitor their progress regularly. To produce a scientist, you have to think of the student as a whole person. Students think, 'As a black student here, how do people see me?' We have people who can help them think through things so that they can focus on chemistry, biology, mathematics, and physics. We encourage these students to get to know the highest achieving students here and to get to know their professors. These students will also have opportunities to work in research labs. They become part of the research culture."

Freeman Hrabowski
University of Maryland—Baltimore County

Encouraging Excellence

NSF values the talented people upon whom U.S. scientific and technological enterprise depends. Since it began, the Foundation has awarded 28,500 fellowships to individuals engaged in study and research. The Foundation annually supports nearly 23,000 senior scientists and 20,000 graduate students—about 2,500 of them as graduate fellows.

Former NSF fellows have won an extraordinary number of honors, including 12 Nobel Prizes.

Focus on Research Careers

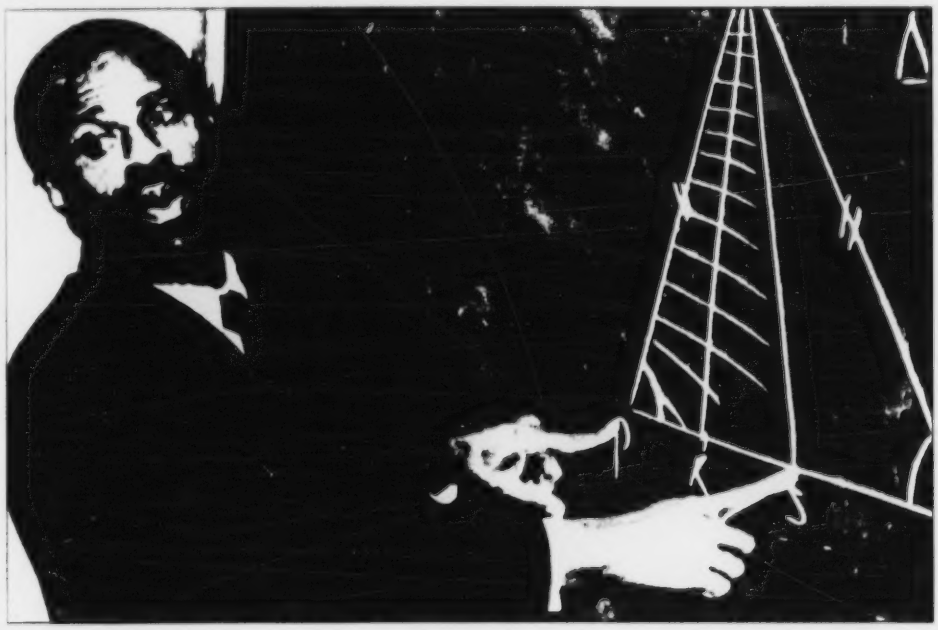
The Foundation operates a variety of research-oriented programs to stimulate interest, enhance entry, and accelerate advancement in science, engineering, and mathematics careers. Some are aimed at the high school level; more are aimed at the undergraduate and graduate levels and beyond. Some research development programs are designed to improve the capabilities of higher education institutions; others focus on the capacities and needs of individuals.

Graduate fellowship and young scholar programs provide promising students with opportunities to engage in research early in their studies. NSF also supports researchers with long and distinguished careers. It places special emphasis on supporting minorities and women. Additionally, the Foundation provides funds for the equipment and services that persons with disabilities need to participate fully in NSF-supported programs.

Two Foundation programs, *Visiting Professorships for Women* and *Faculty Awards for Women*, have provided scientific career opportunities for 355 women over the last decade. The increased visibility has accelerated many careers. The program also provides role models for female colleagues.

"The step from associate professor to full professor is difficult. This is a great moment to have support. FAW is a very prestigious award that will provide flexibility to conduct my research."

Diana Farkas
Virginia Polytechnic Institute and State University



Since 1982, *Research Improvement in Minority Institutions* has helped develop the research and training capabilities of 240 faculty in more than 100 departments in colleges and universities with substantial minority enrollments. Some of these institutions have recently become known for their research centers, thus enabling them to compete more successfully for other funding.

To increase scientific and engineering research at leading minority institutions, NSF has established eight minority research centers of excellence—located at Clark Atlanta University, Howard University, Alabama A&M University, Hampton University, the University of Puerto Rico, Meharry Medical College, City College (of New York), and the University of Texas at El Paso. These centers conduct competitive research, and develop and strengthen graduate science and engineering programs involving nearly 400 students annually.

To help secondary students reach informed decisions about potential careers in science, NSF initiated the *Young Scholars Program* in 1988. In its first four years, this program supported more than 272 projects, which provided enrichment experiences in science, mathematics, and engineering to more than 17,000 high-ability or high-potential high school students during the summers of 1988-1991.

"The honor of being an NSF Young Scholar combined with the fact that it doesn't cost money means that it offers the pinnacle experience to a poor student. We essentially mount two scientific expeditions each summer. We assemble teams of a scientist-researcher, a teacher, a logistics person, one student from a previous summer's team, and ten team members. We have a total experience, living together for 42 days.

"Two years ago, a kid came to us who had the profile of someone who should be in trouble. But he was given a chance to be a Young Scholar his junior year and became the outstanding Young Scholar here that year. We brought him back the next year in another part of the program to work for us. He presented a paper at the American Fisheries Society meeting and graduated valedictorian of his high school class. He just completed his first semester at Oregon State University with a 4.0."

Jeffry Gottfried
Oregon Museum of Science and Industry

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Monitoring Trends

An innovation in education can take many years to mature. The ongoing monitoring of educational trends and the continual evaluation of educational programs is essential to making informed decisions.

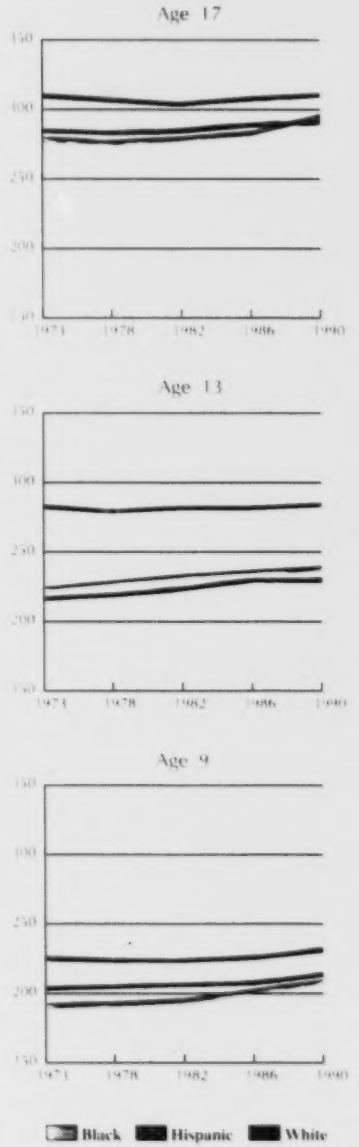
To delineate initiatives that will productively guide science, mathematics, and engineering education, NSF supports the collection and analysis of data on national and international trends in achievement. Information about general trends and about the outcomes of NSF-supported activities is disseminated to policymakers, curriculum supervisors, scientists, classroom teachers, and others involved in improving U.S. science and mathematics education.

Beginning in 1993, NSF will publish a biennial report on the status of science, mathematics, and engineering education that will gauge progress toward our goals for excellence. Such monitoring and evaluation will help plan future directions for the Foundation, thereby ensuring effective interactions with education change agents and public policymakers.

Over the next five years, NSF will also be evaluating all of its educational programs and devising more effective ways to disseminate information about the outcomes of projects.

Multiplying Inequalities, an NSF-supported study, found that in secondary schools where low-income African-American and Hispanic students are the majority, students have limited access to the "gatekeeping" courses—algebra in junior high school and calculus in senior high school—that prepare them for further mathematics and science study. The researchers suggest that new resources for materials and staff go first to schools with the greatest need—to help ensure high-quality instruction for all students.

Trends in Average Mathematics Proficiency by Race/Ethnicity



Source: "Trends in Academic Progress" 1991 - NCES 91-1264

The numbers shown on the vertical axis represent the National Assessment of Educational Progress proficiency scale, which ranges from 0 to 500.

"I see an emphasis at the Foundation on several things that I like very much—the first is having antennae out so that we can assess programs and do more of what is working. Another exciting trend is the notion of technical assistance to groups of projects. This means that when a number of projects are funded, experts can be available for advice. Also, moving toward large programs which take a systems approach is very useful. For example, we know that teachers need preparation in order to be able to use new curriculum. Funding projects which include all of the components necessary for change makes a lot of sense."

Iris Weiss
Horizon Research, Inc.

Evaluators gather information to assess program effectiveness and to review teacher enhancement projects.

Some recent evaluator remarks:

"Numerous teachers commented on how they had changed their style of teaching to reflect what they had learned in NSF teacher enhancement projects."

"Several teachers commented that the technology and methods learned . . . were particularly useful in classes with low ability students."

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Coordinating a Federal Strategy

Among federal agencies, the National Science Foundation plays a major role in federal support of mathematics, science, and engineering education. Its programs address all students at all levels. NSF education expenditures make up nearly one-quarter of the total federal science and mathematics education effort.

Since Fiscal Year 1986, the NSF education budget has increased fivefold, from $92 million in 1986 to $465 million for 1992.

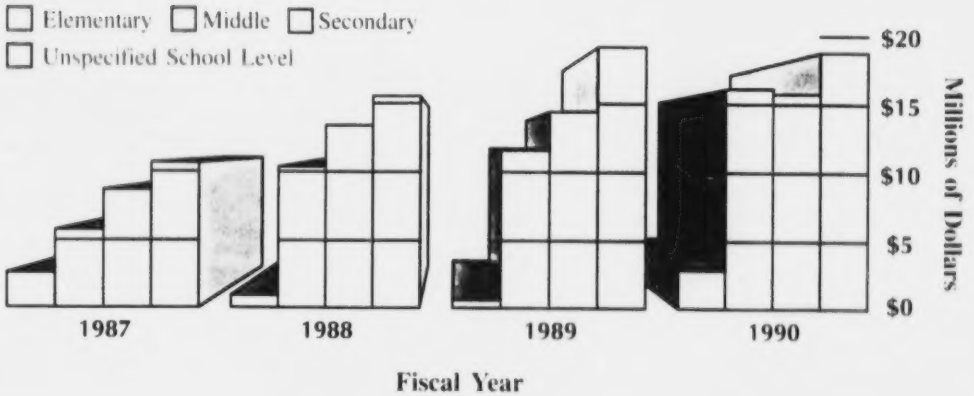
To further highlight the Foundation's commitment to education for the next decade, a memorandum of understanding between NSF and the Department of Education was signed early in 1992. This signals a new era of cooperation between these two federal agencies.

Federal Coordinating Council for Science, Engineering, and Technology

NSF, with the Departments of Energy and Education, helps lead the efforts of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) Committee on Education and Human Resources (CEHR). Representing 16 federal agencies and institutions that are major players in science and mathematics education, FCCSET helps coordinate the nation's federal education agenda.

NSF Teacher Enhancement Funding by Level of Education

Fiscal Years 1987-1990



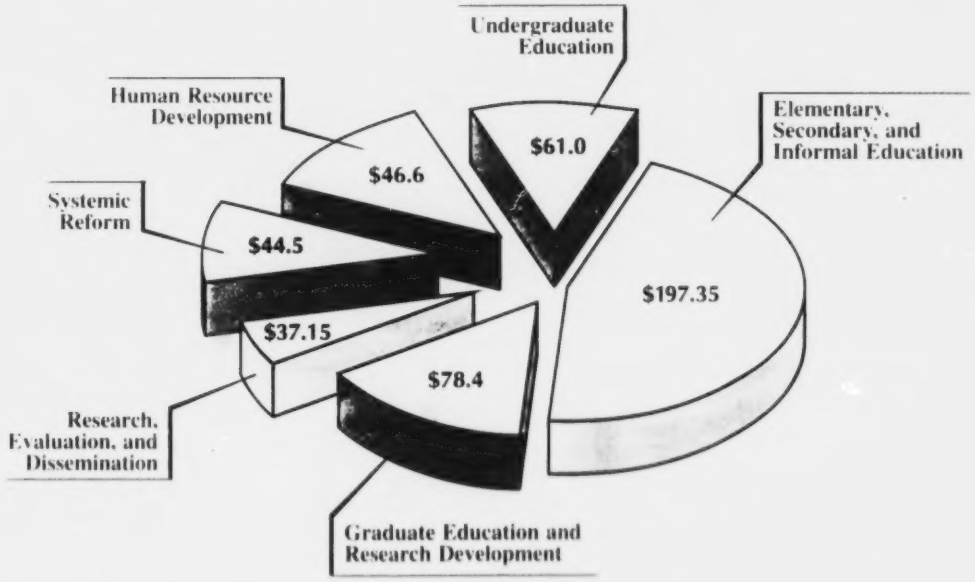
NSF chaired the initial two years of the CEHR Working Group on the Federal Program Plan, which developed a priority framework to direct federal efforts in meeting national education goals for competency, achievement, and literacy in science, mathematics, engineering, and technology education and generated the first comprehensive inventory of federal science and mathematics programs. For Fiscal Year 1993, FCCSET-CEHR has requested $2.1 billion for programs supporting precollege, undergraduate, and graduate education, as well as public science literacy.

FCCSET's Committee on Education and Human Resources coordinates the development of federal strategic objectives that define the federal role in meeting national science and mathematics education goals. Strategic objectives of the federal plan call for: improved science and mathematics performance; a strong precollege teacher workforce; an adequate pipeline for the science and technology workforce, including increased participation of underrepresented groups; and improved public science literacy.

NSF Education and Human Resources Directorate Budget

Fiscal Year 1992

(in millions of dollars, total $465 million)



For Further Information

Program Announcements, Solicitations, and Guidelines

Precollege	Assessing Student Learning: Science, Mathematics and Related Technology Instruction at the Precollege Level in Formal and Informal Settings (NSF90-152)
	Career Access: Summer Science Camps, Partnerships for Minority Student Achievement, and Comprehensive Regional Centers for Minorities (NSF91-129)
	Materials Development, Research, and Informal Science Education (NSF91-130)
	Teacher Preparation and Enhancement (NSF91-105)
	Young Scholars Program - FY 1993 (NSF92-9)
Undergraduate	Alliances for Minority Participation (NSF91-129)
	Curriculum Development in Mathematics: Calculus and the Bridge to Calculus (NSF91-125)
	Instrumentation and Laboratory Improvement (NSF91-84)
	Research Careers for Minority Scholars (NSF91-129)
	Undergraduate Course and Curriculum Development Program (NSF91-50)
	Undergraduate Faculty Enhancement Program (NSF91-131)
	Undergraduate Science, Engineering, and Mathematics Education (NSF91-133)
Graduate and Above	NSF Graduate Research Fellowships (NSF91-72)
	NSF Minority Graduate Research Fellowships (NSF91-73)
	Graduate Research Traineeship Program (NSF92-29)
	NSF-NATO Postdoctoral Fellowships in Science and Engineering 1991-92 (NSF91-88)
	Young Investigator Awards FY 1992 Program (NSF91-112)
	Presidential Faculty Fellows Program (NSF91-103)
Multiple Levels	Human Resource Development for Minorities in Science and Engineering (NSF91-129)
	Office of Studies and Program Assessment (NSF88-69)
	Research on Key Issues in Science and Engineering Education (NSF90-149)
	Statewide Systemic Initiatives in Science, Mathematics, and Engineering Education (NSF90-47)
General	Guide to Programs, Fiscal Year 1992 (NSF91-80)
	Publications of the National Science Foundation (NSF92-11)

Directories of Awards

Applications of Advanced Technologies. Summary of Awards, Fiscal Years 1987–1990 (NSF91-97)	**Precollege**
Directory of NSF-Supported Teacher Enhancement Projects (NSF91-40)	
Directory of NSF-Supported Young Scholars Projects (NSF91-47)	
Informal Science Education. Summary of Awards, Fiscal Years 1987–1990 (NSF91-99)	
Instructional Materials Development. Summary of Awards, Fiscal Years 1987–1990 (NSF91-96)	
Research in Teaching and Learning. Summary of Awards, Fiscal Years 1987–1990 (NSF91-98)	
Directory of NSF-Supported Undergraduate Faculty Enhancement Projects. Short Courses and Workshops for Undergraduate Faculty. Summer 1992 (NSF91-135)	**Undergraduate**
Instrumentation and Laboratory Improvement Program. FY 1991 Awards (in press)	
Undergraduate Course and Curriculum Development Program. FY 1991 Awards (in press)	
A Selected List of Fellowship Opportunities and Aids to Advanced Education for United States Citizens and Foreign Nationals (NSF88-119)	**Postgraduate**

To request a copy of any of these publications, call the NSF Publications Department at (202) 357-7861.

Credits

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The Smithsonian Institution - National Science Resources Center, page 11, page 19 right, page 27 bottom.

RAND Corporation, p. 12 top.

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Children's Television Workshop, page 20 right, page 21, page 23 top.

Matthew Barrick, The Catholic University of America, page 23 bottom.

Oregon Museum of Science and Industry, page 25.

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